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Title: Strength, Fracture Evolution, and Permeability Changes from Confined Brazilian Tests on Sandstone

Author(s): Hagengruber, Tyler Louis

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Strength, Fracture Evolution, and Permeability Changes from Confined Brazilian Tests on Sandstone

Tyler Hagengruber

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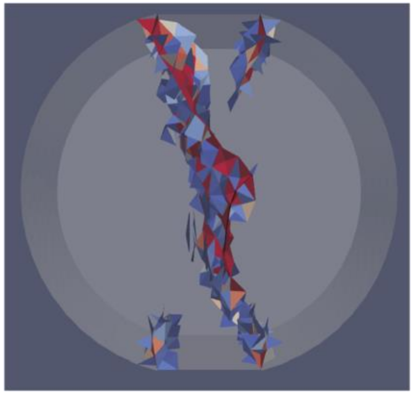
Outline

1. Introduction
2. Materials and Methods
3. Strength and Failure Results
4. Permeability and Fracture Evolution Results
5. Conclusions

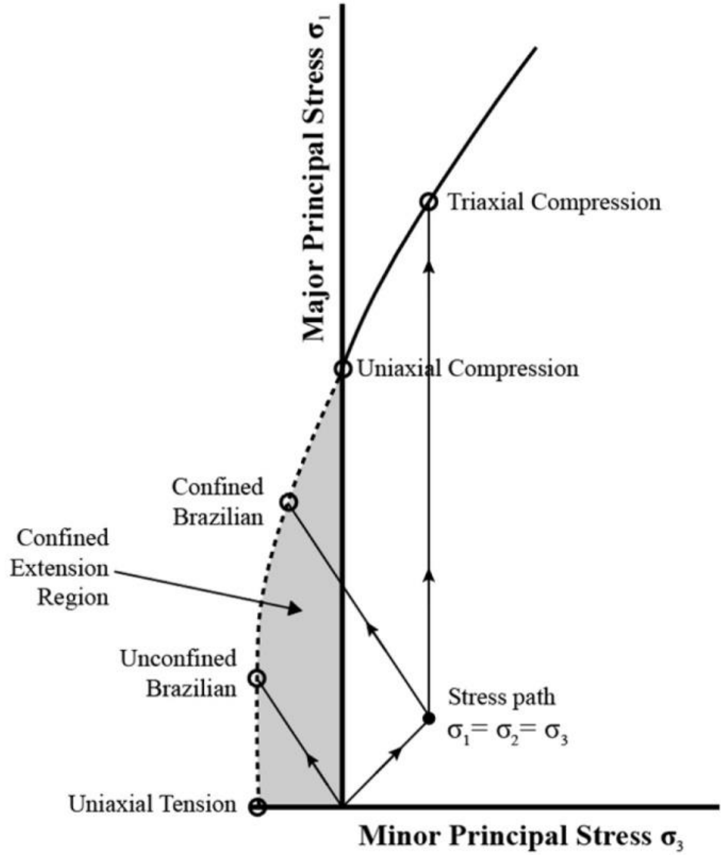
Introduction

Background and Motivation

- Collaborative research between UNM and LANL
  - Phase I – Quasi-static Brazilian test with concurrent permeability measurements.
  - **Phase II – Quasi-static confined Brazilian test with concurrent permeability.**
  - Phase III – Dynamic testing.
- Development of HOSS (Hybrid Optimization Software Suite)



Strength in the Confined Extension Region



Failure curve in principal stress (σ_1 -σ_3) space. The confined extension region is shown as shaded area. The stress paths of different strength tests are shown, including the confined Brazilian test. Figure modified from Patel and Martin, 2018.

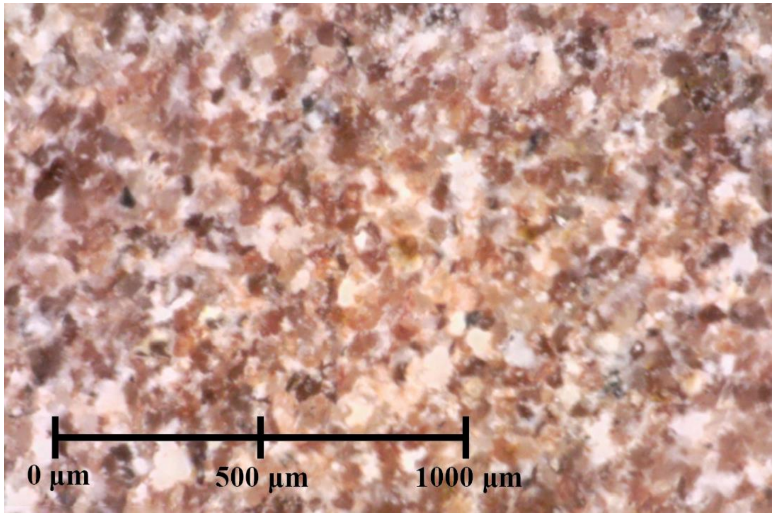
Objectives

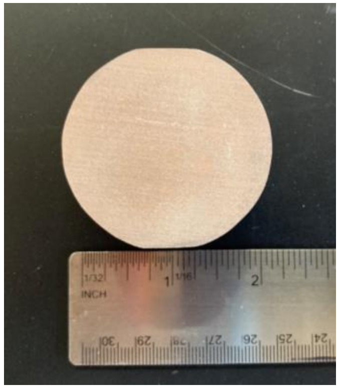
- Understand failure conditions of rock in the confined extension region
- Understand the conditions under which microcracks and permeability develop in the confined extension region
- Compare and analyze numerical simulations with experimental results

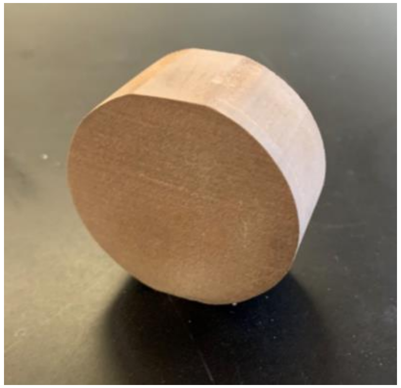
Materials and Methods

Materials

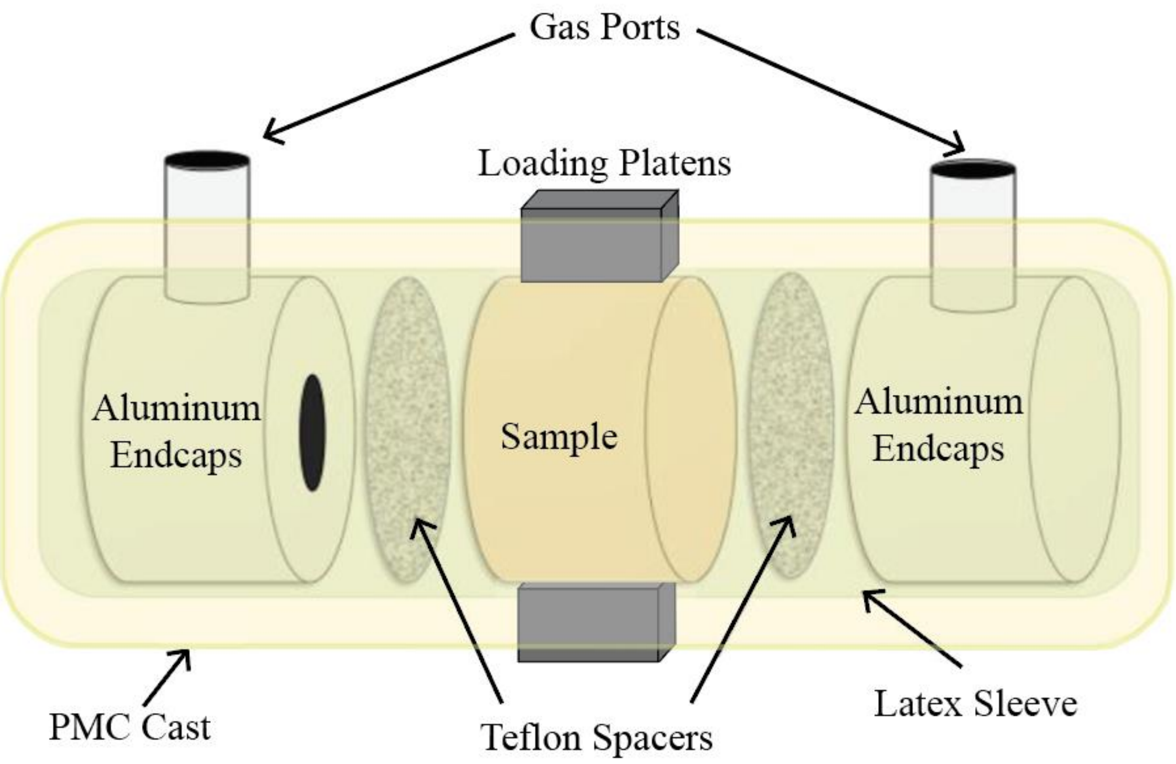
- Royal Red Sandstone – quarried from Kanab, Utah
  - Small grain size (20-100 microns)
  - Homogenous
  - Relatively weak sandstone
- Confined Flattened Brazilian Tests
- Sample Dimensions
  - 50.8 mm diameter
  - 25.4 mm thickness
  - 1.0 mm flattened





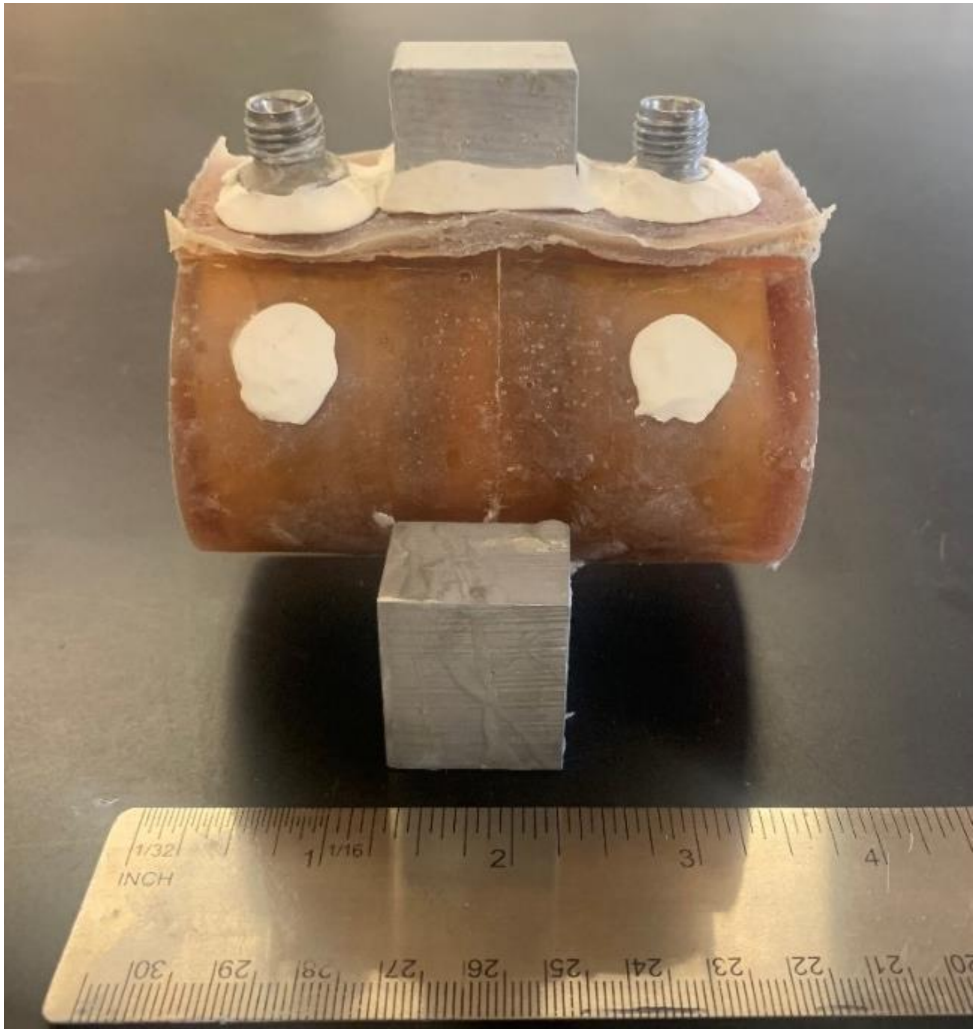


Sample Preparation

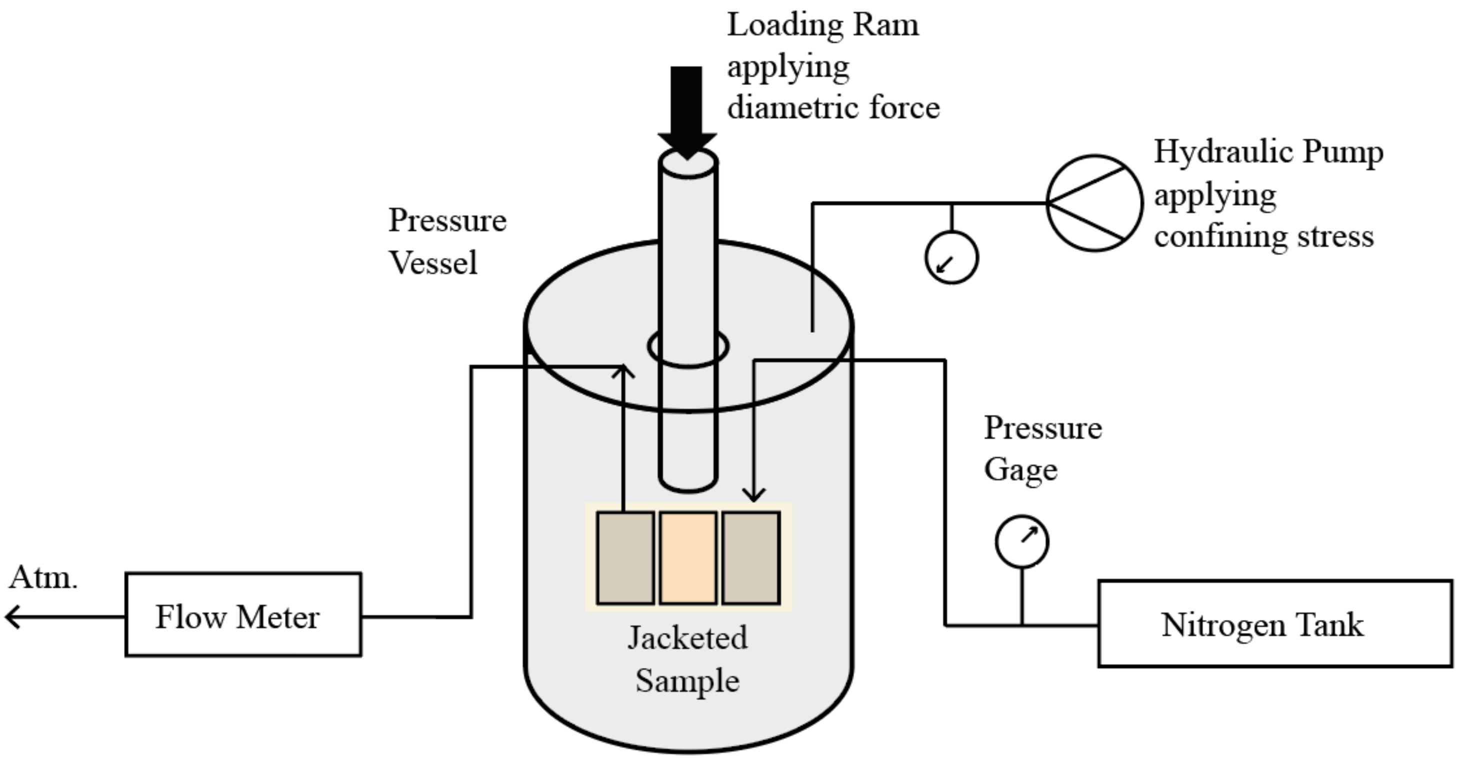


Schematic of the sample jacketing construction modified from Boyce (2019).

Sample Preparation

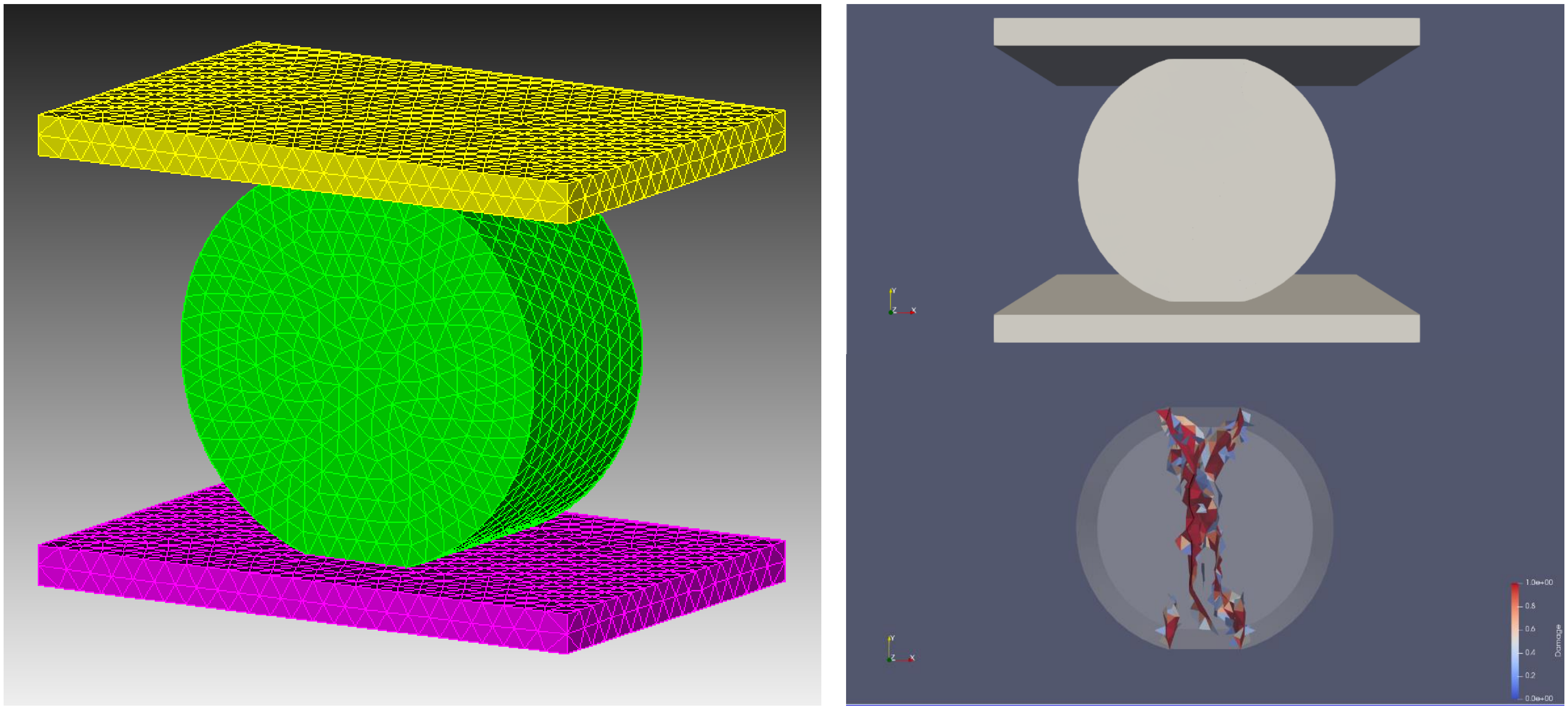


Experimental Setup



Schematic of the permeability and loading system inside the pressure vessel, modified from Boyce (2019).

Experimental Setup



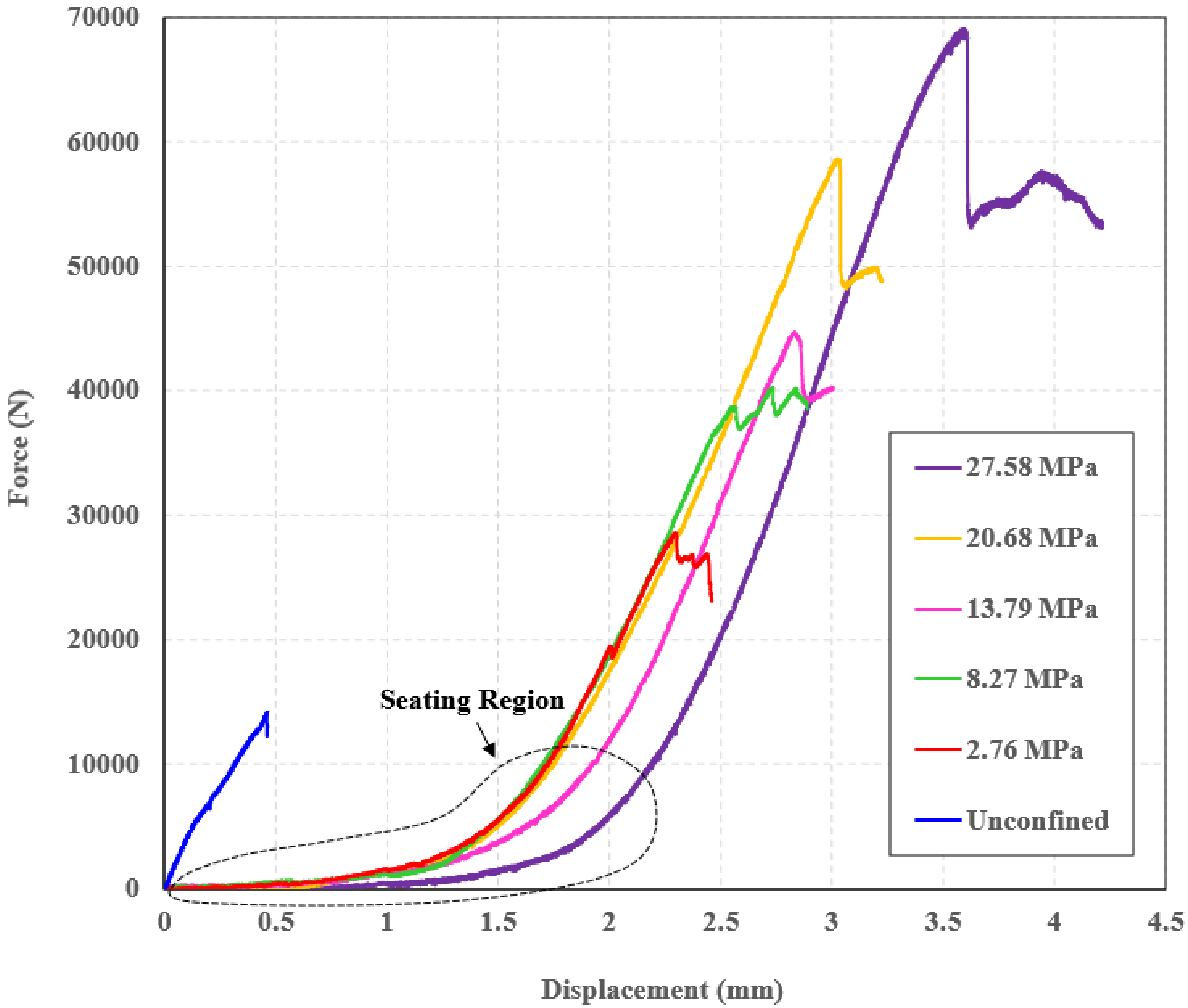
Geometric representation of a confined Brazilian test (left) and numerical simulation results observed using Paraview (right).

Testing Matrix

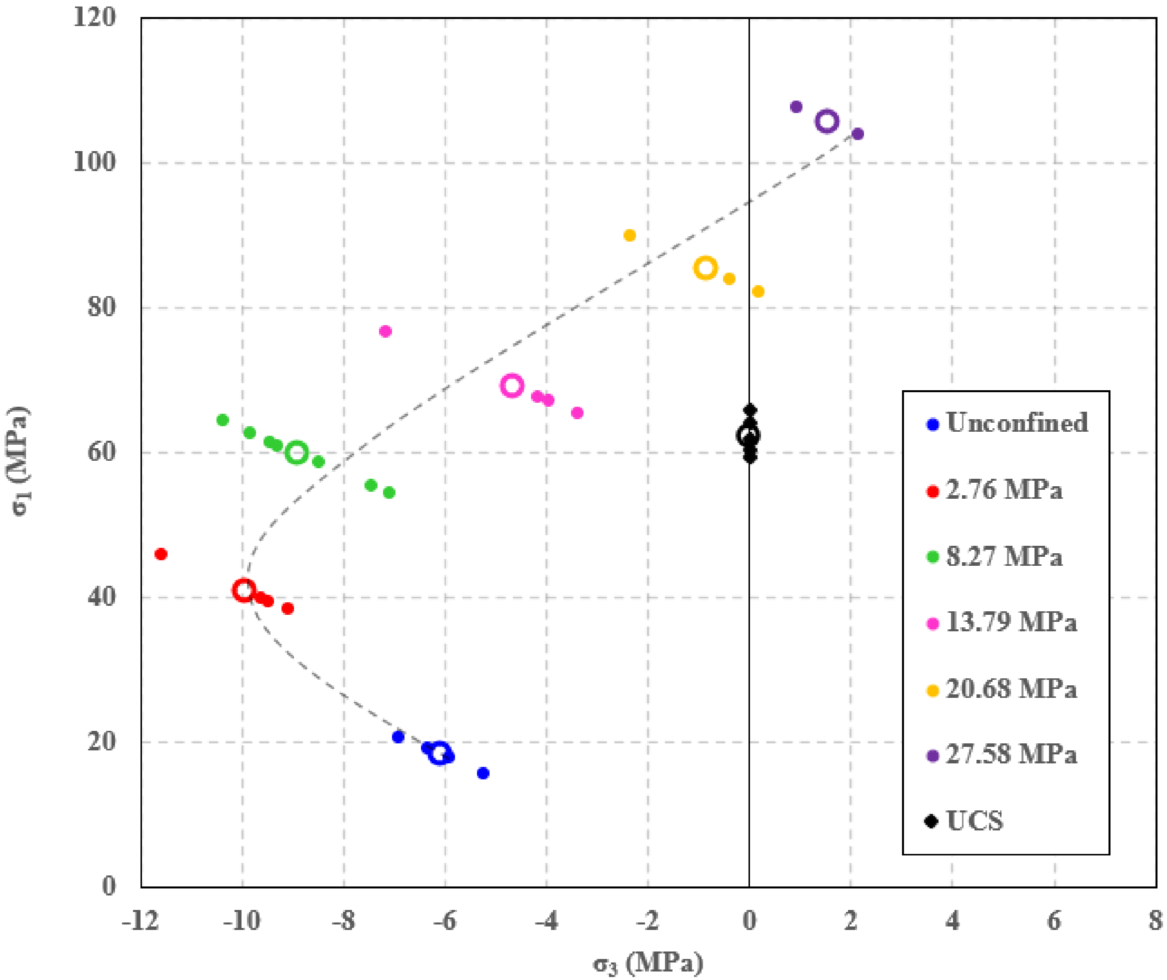
Test Type	Sample #s	Confining Pressure (MPa)					
		0	2.76	8.27	13.79	20.68	27.58
To Failure (Includes Perm.)	A-1 to A-24	4 (0)	4 (3)	7 (5)	4 (3)	3 (2)	2 (2)
Porosity and Permeability pre-failure	B-1 to B-7	0	7	0	0	0	0

Strength and Failure Results

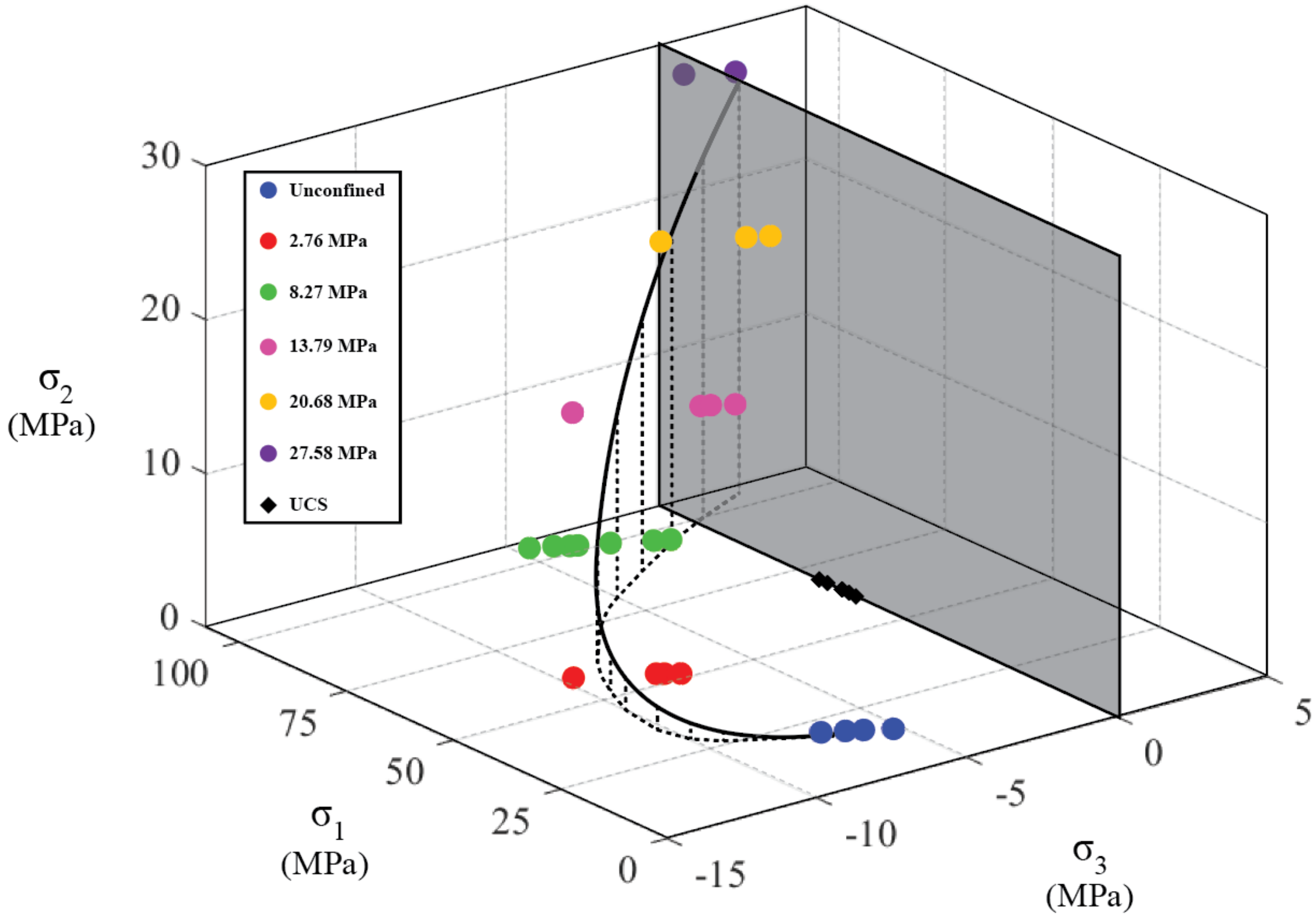
Force - Displacement



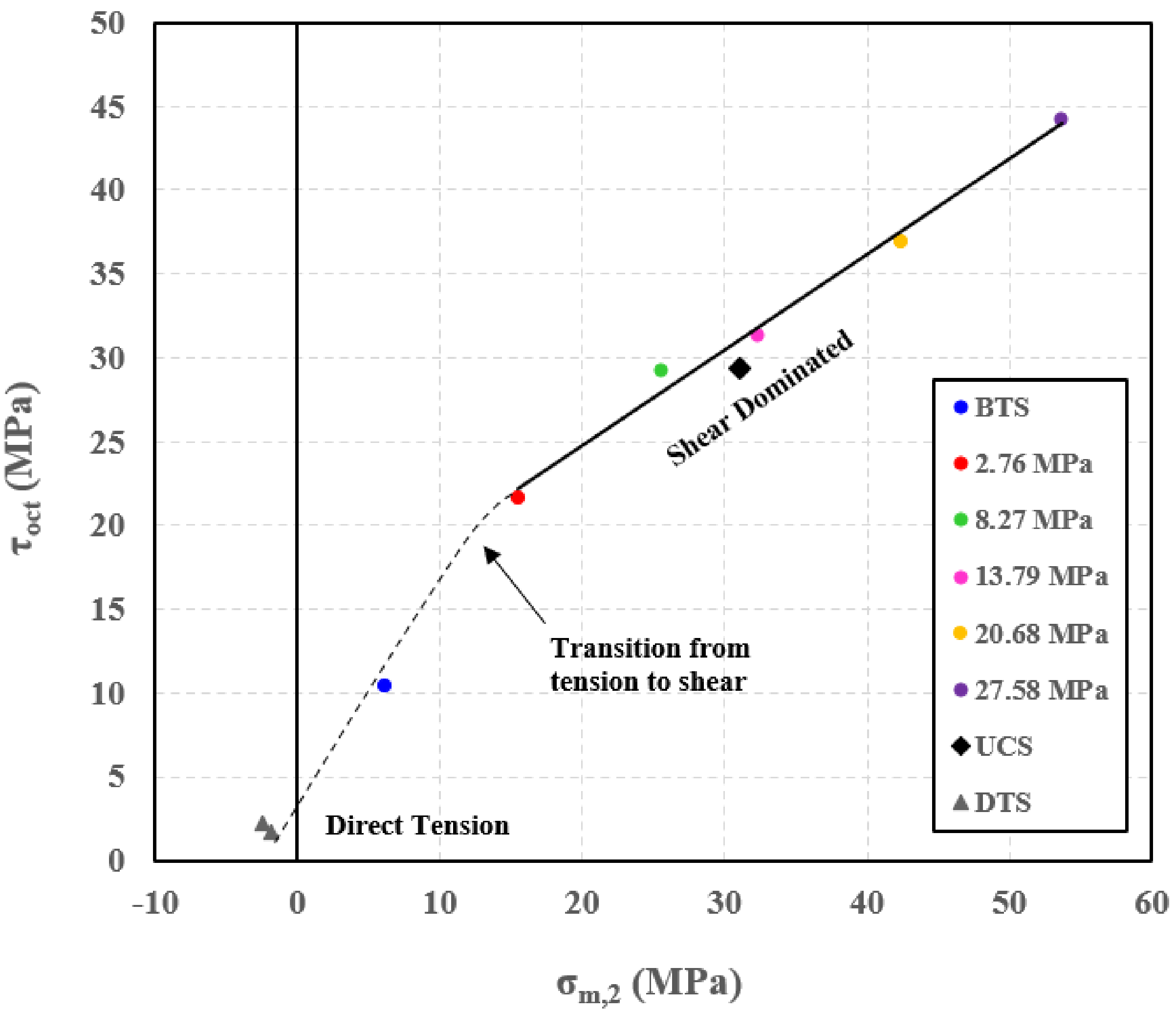
Principal Stresses at Failure



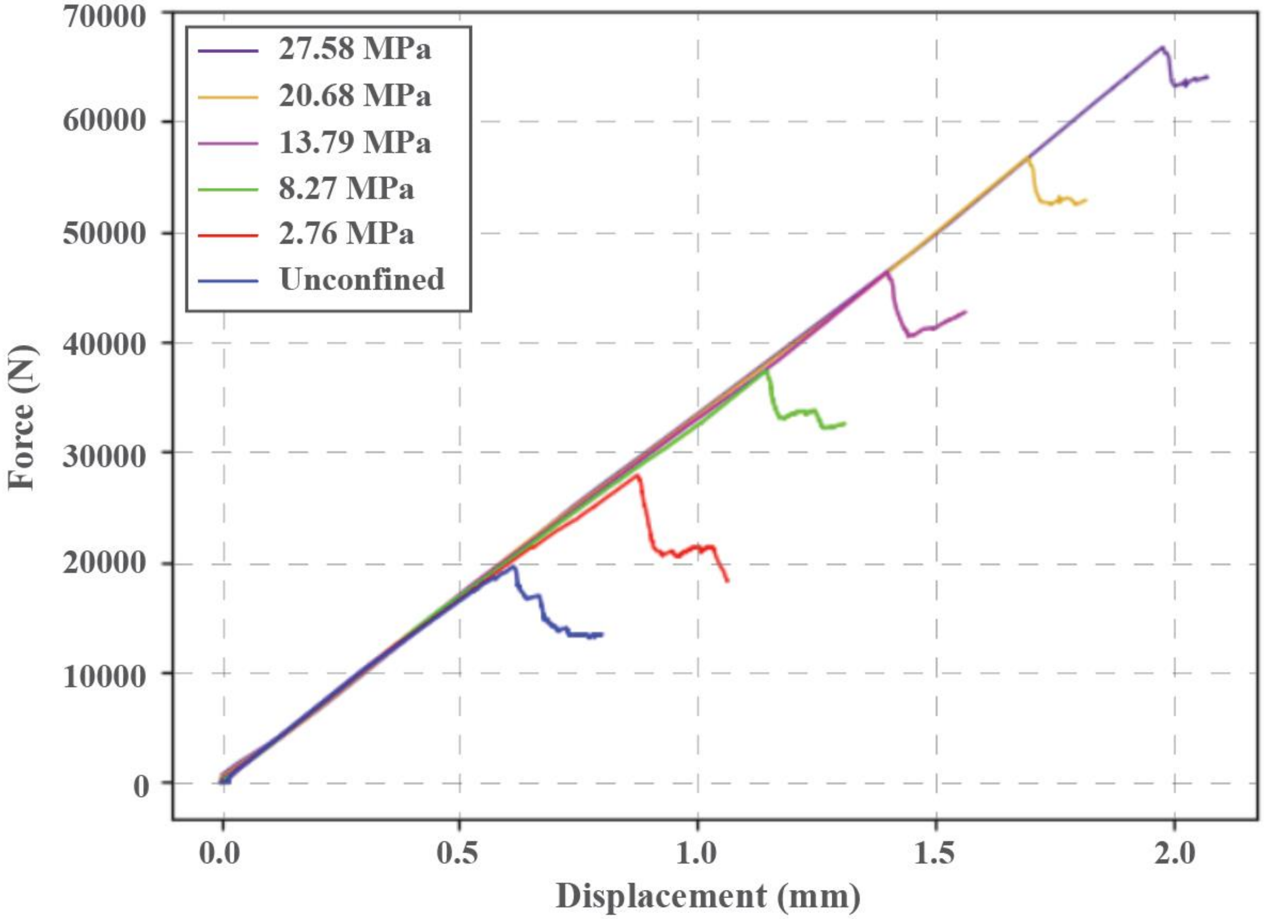
Principal Stresses at Failure



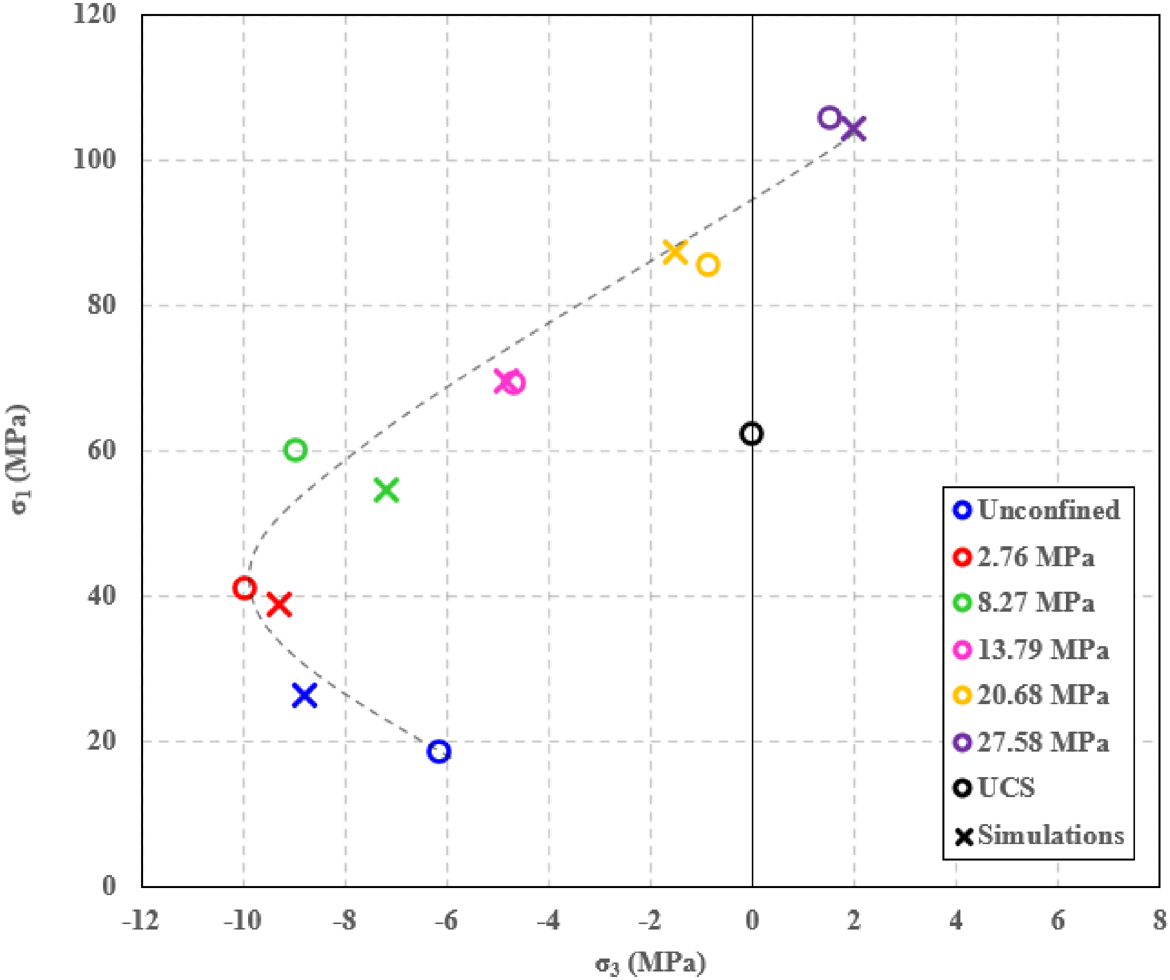
Mogi-Coulomb Failure Criterion



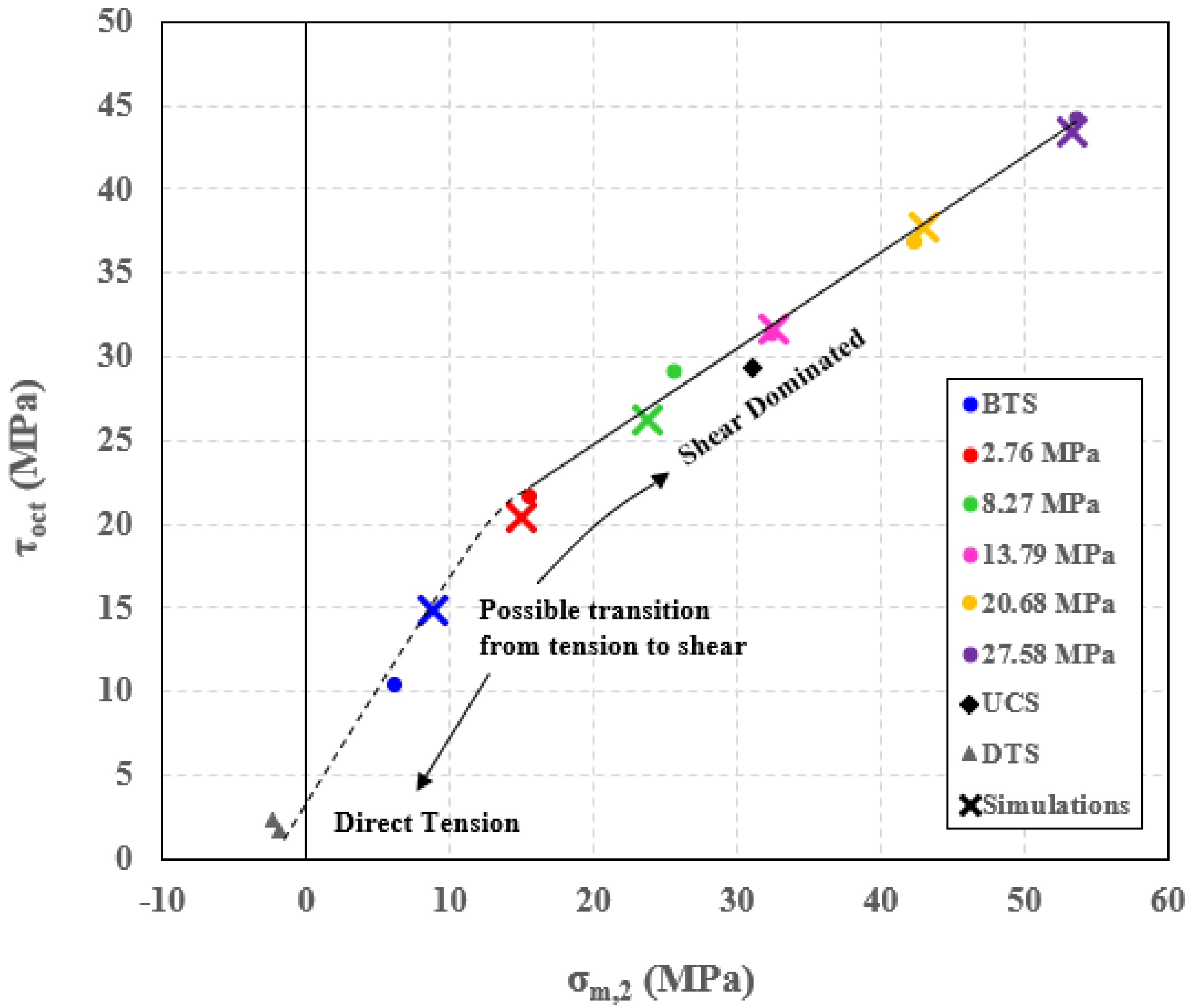
Numerical Results using HOSS



Numerical vs. Experimental Stresses

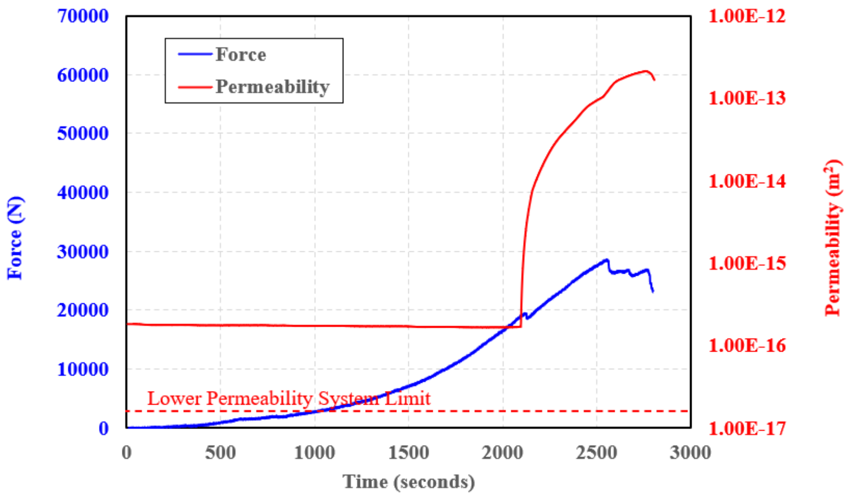


Numerical vs. Experimental Stresses

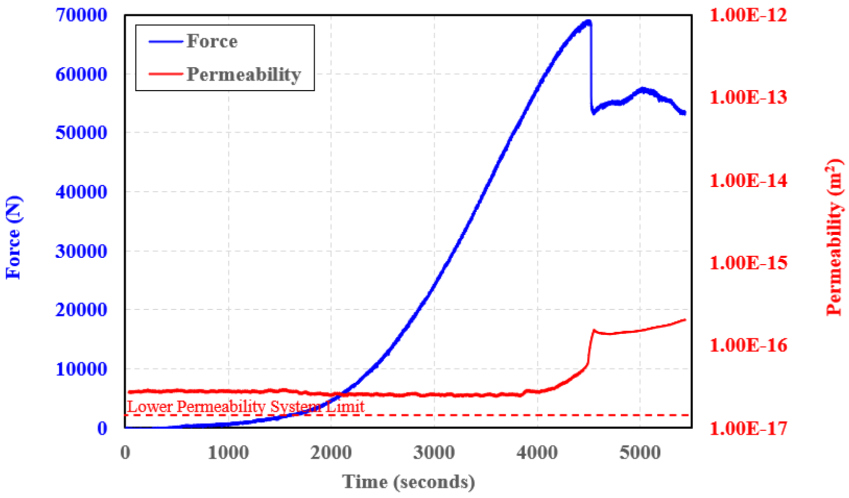


Permeability and Fracture Evolution Results

Force and Permeability vs. Time

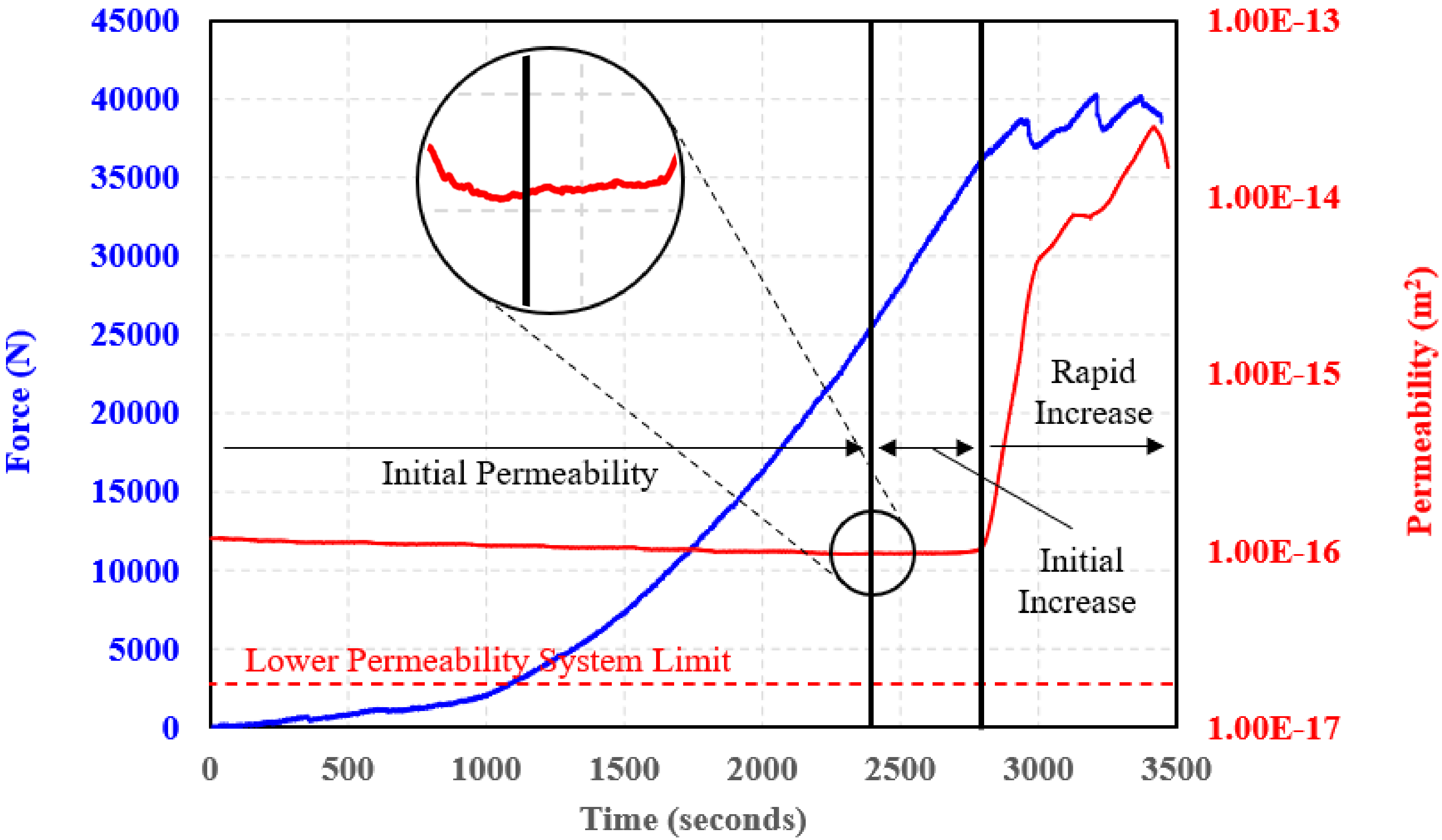


2.76 MPa

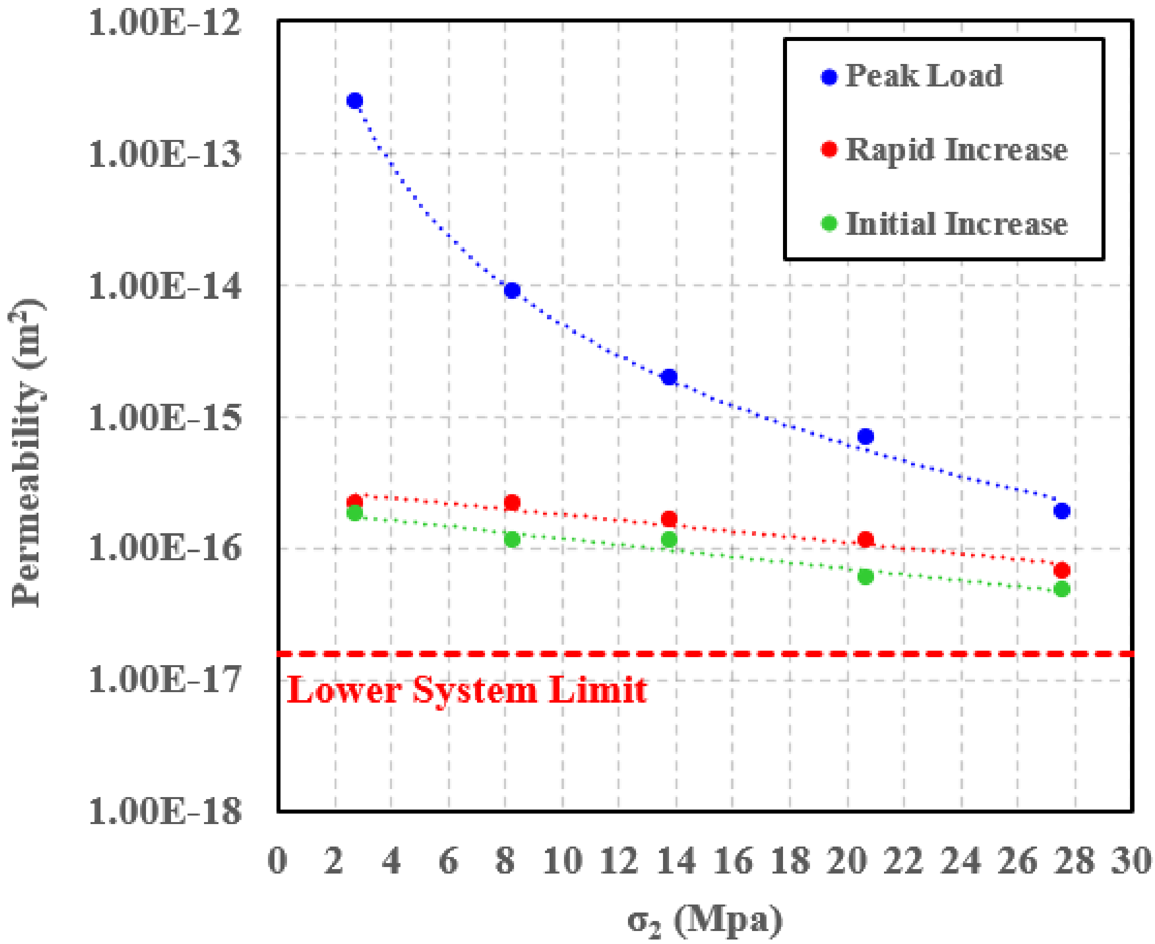


27.58 MPa

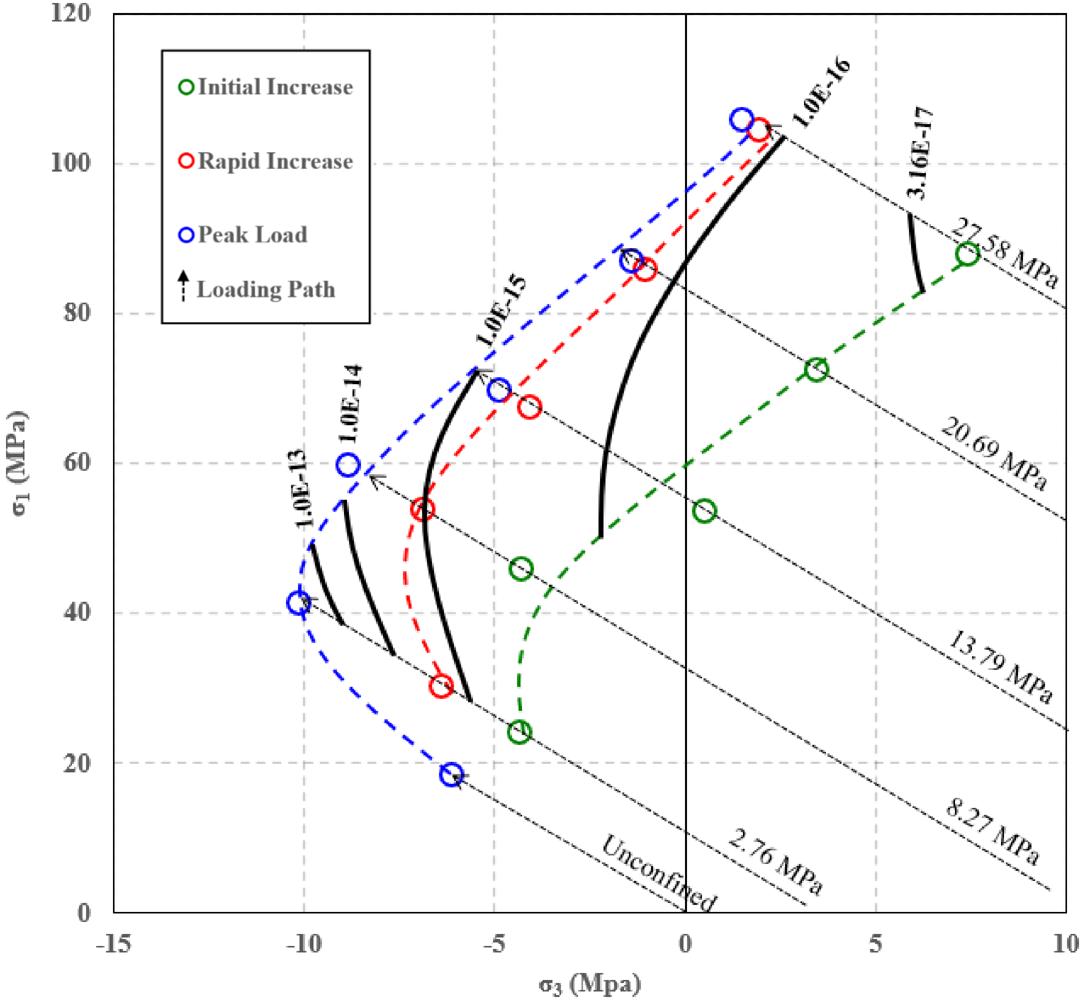
Permeability Thresholds



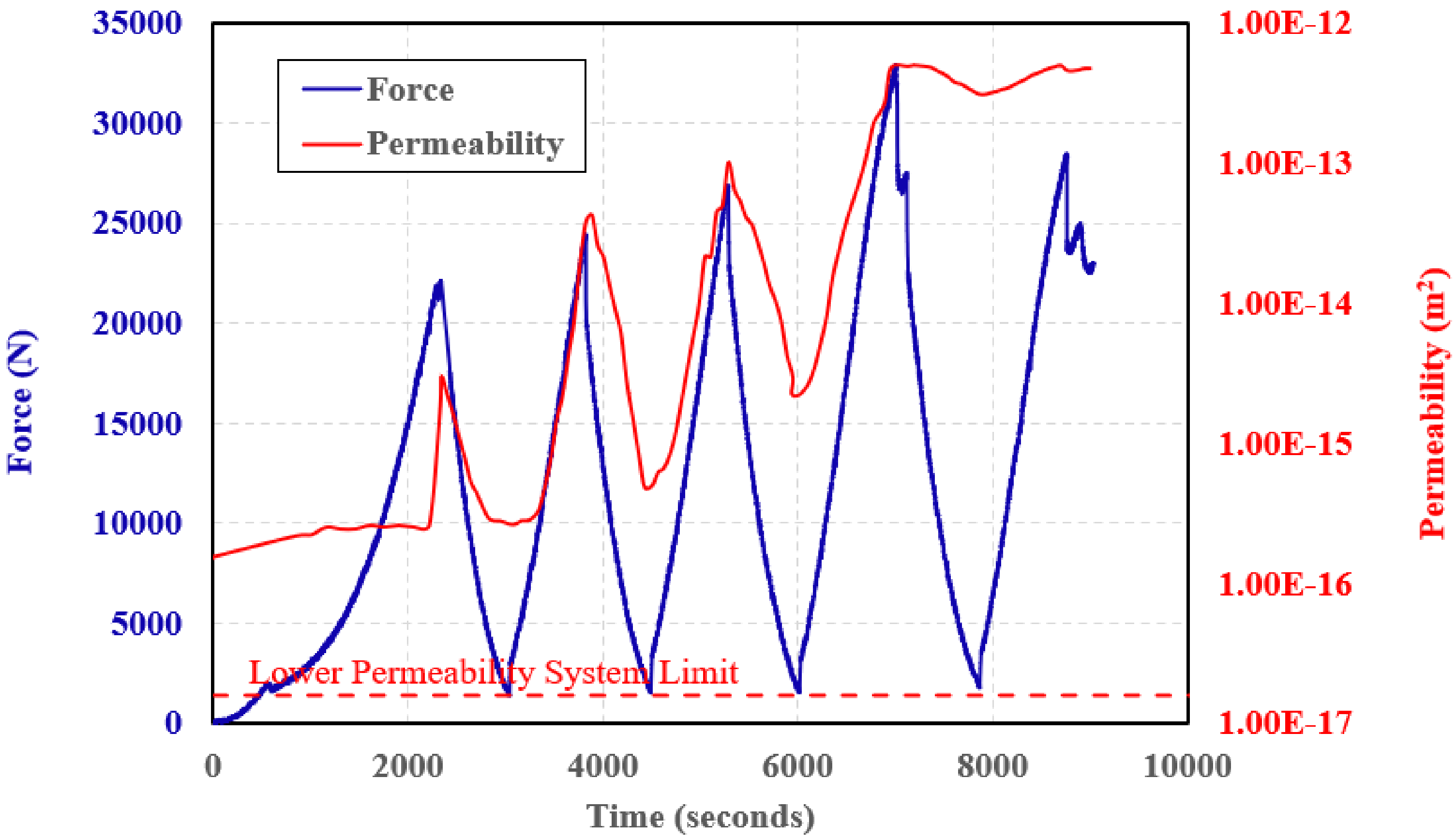
Permeability vs. Confining Stress



Permeability Thresholds in Principal Stress Space



Unloading and Reloading Cycles



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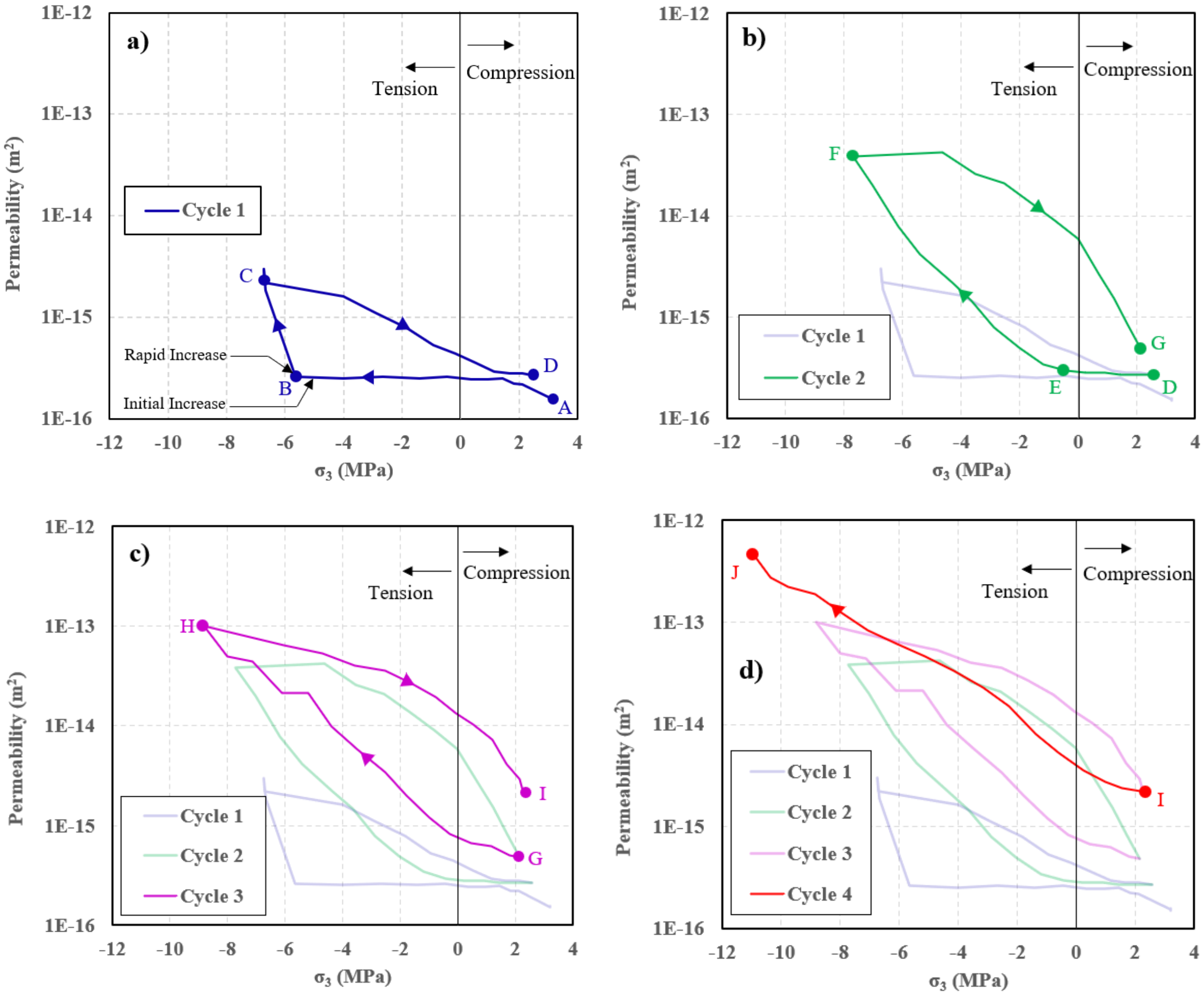
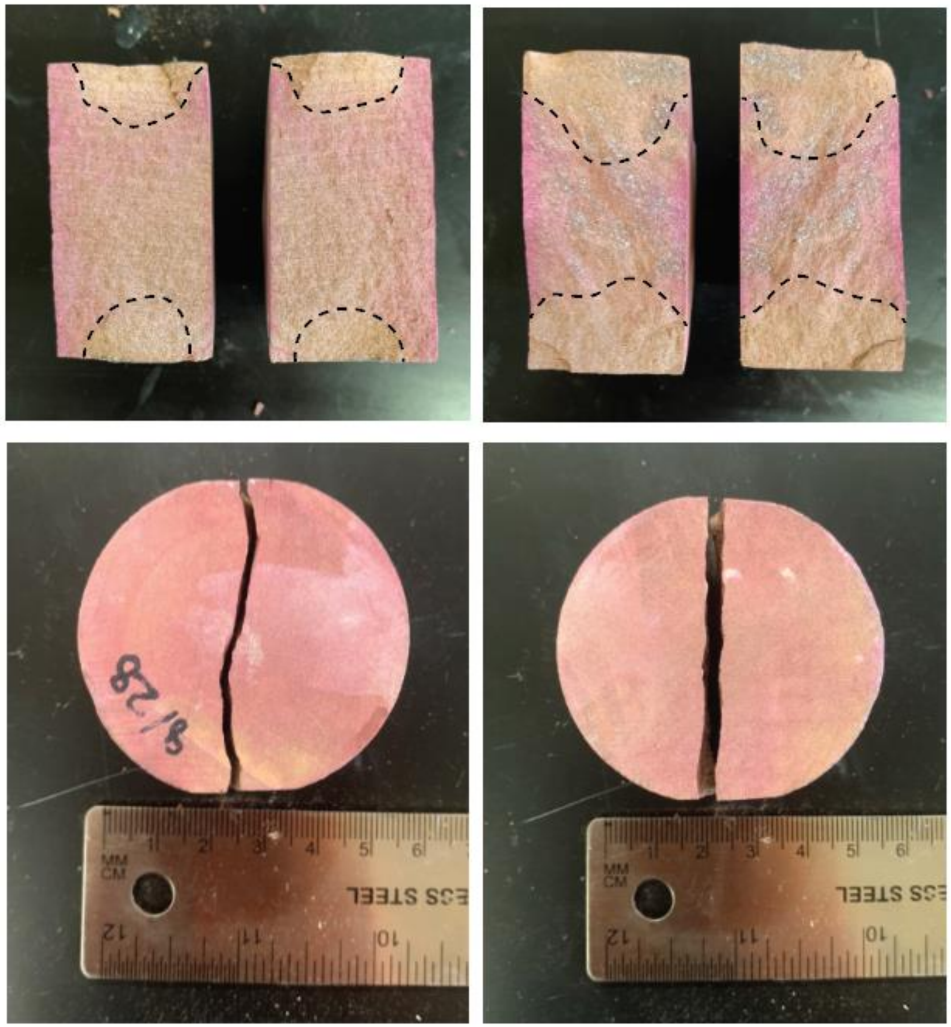
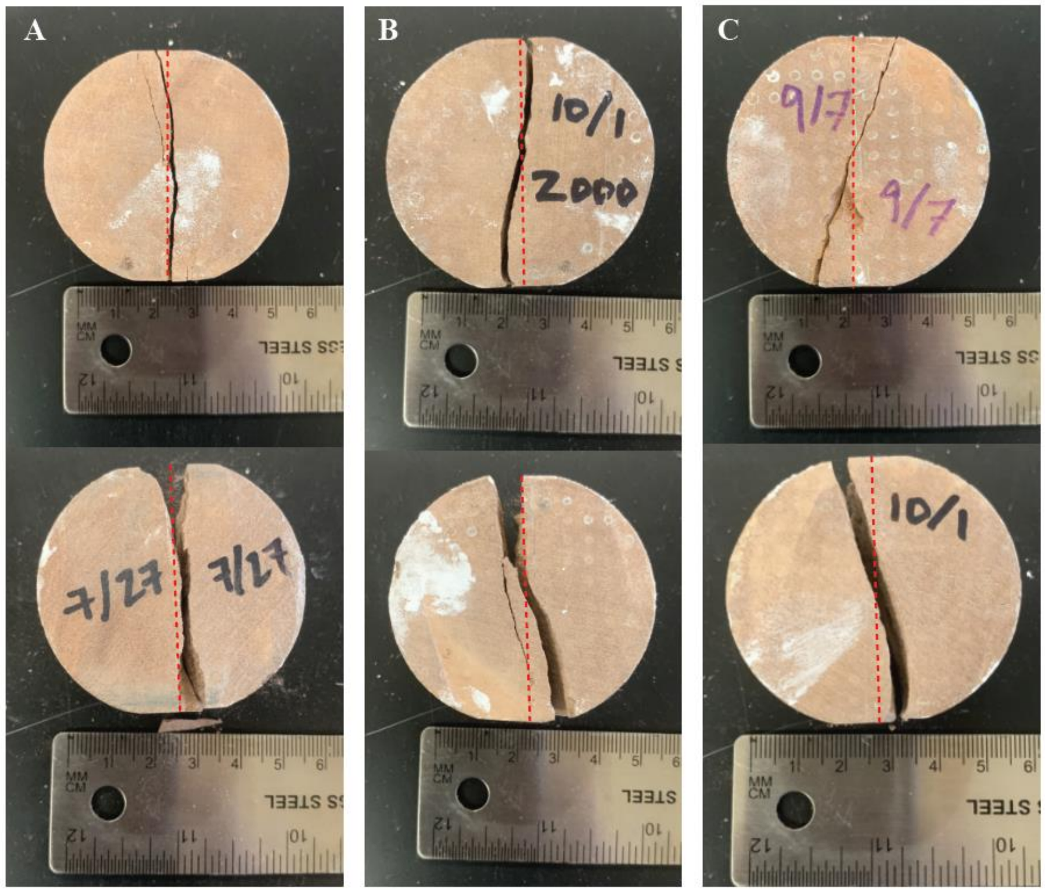


Observation of Fractures



Observation of Fractures

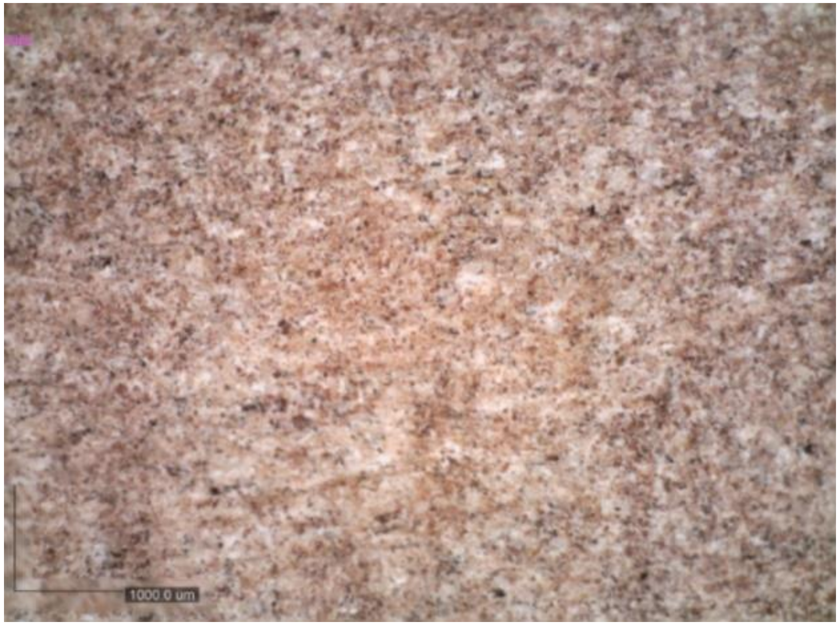
2.76 MPa | 13.79 MPa | 27.58 MPa



Observation of Fractures

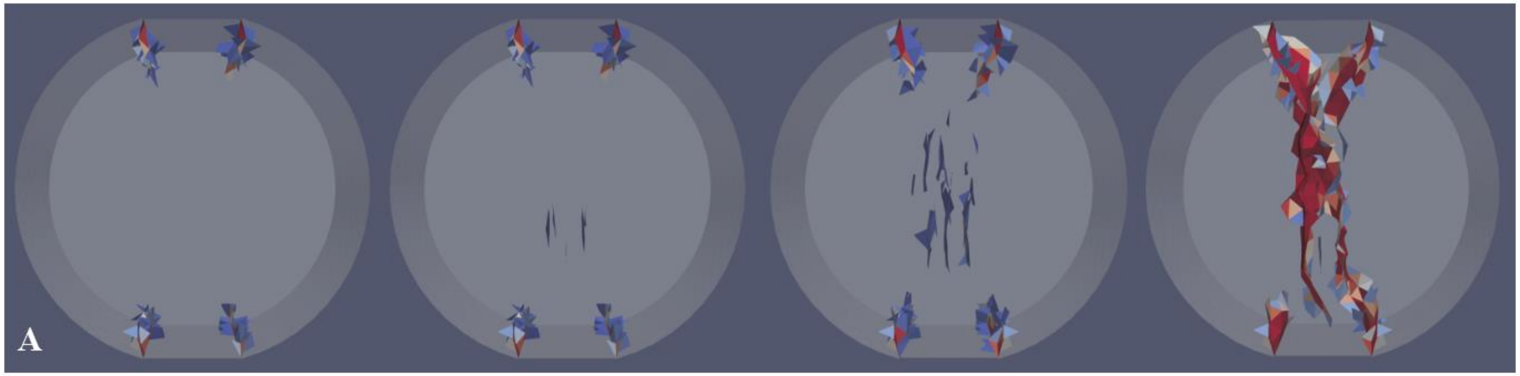
2.76 MPa

27.58 MPa

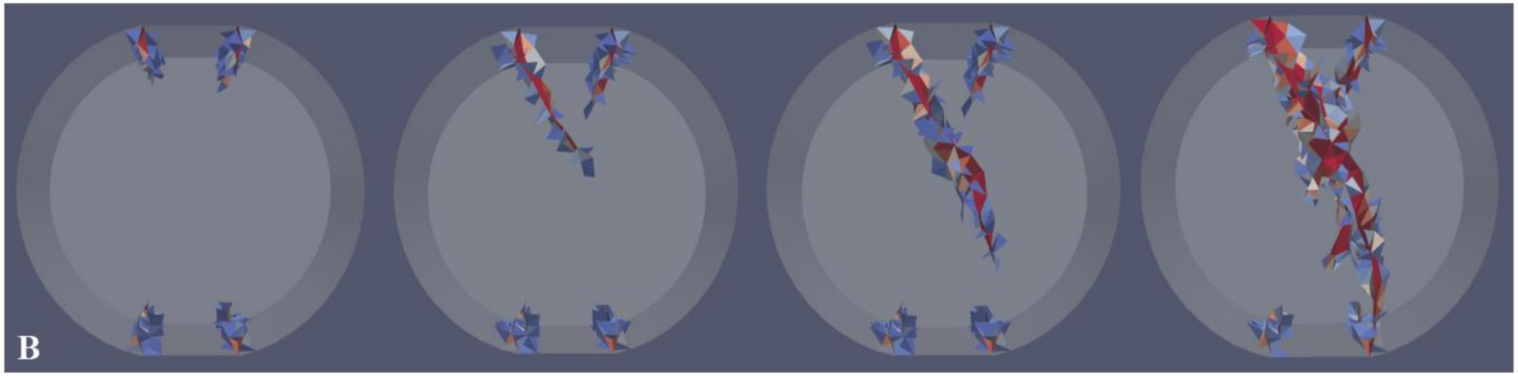


Observation of Fractures

2.76 MPa

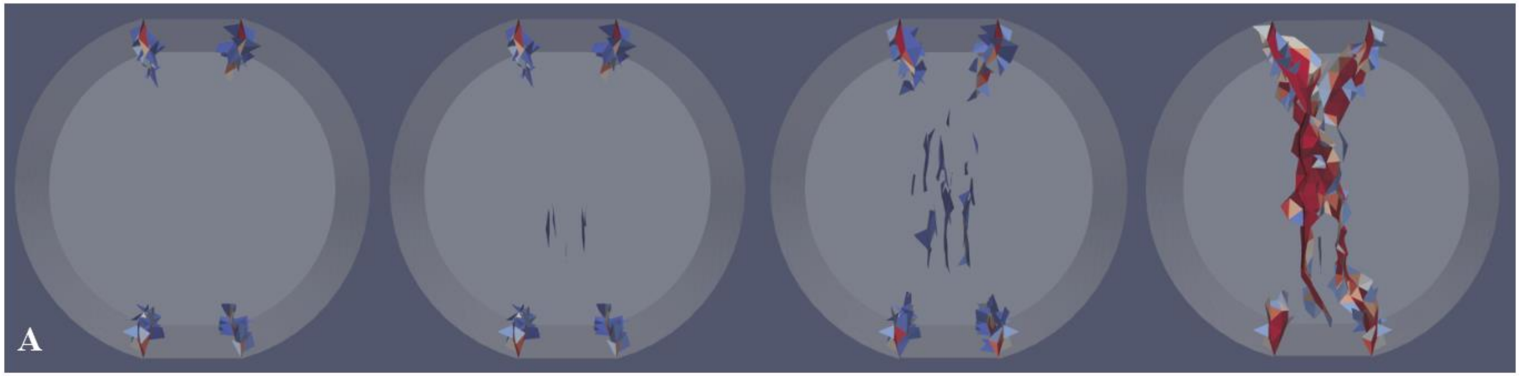


27.58 MPa



Observation of Fractures

2.76 MPa



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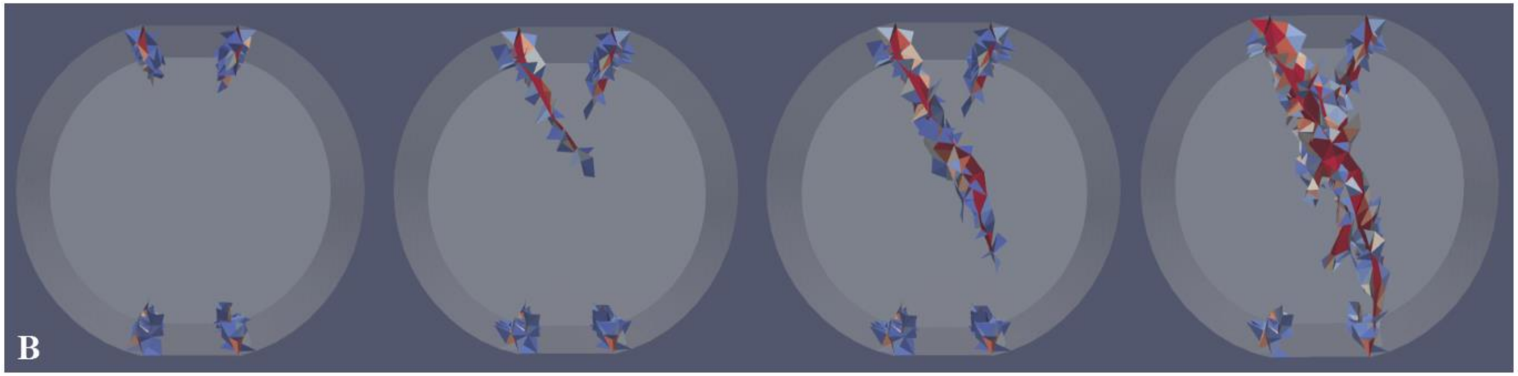


Conclusions

Conclusions

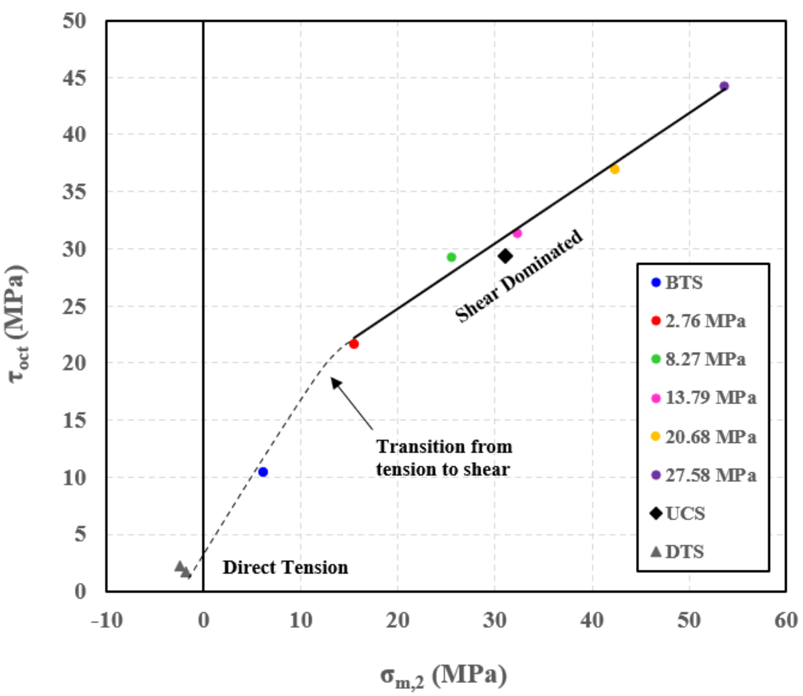
- Strength and Failure
  - Strength was a strong function of the intermediate principal stress
  - The failure data is well fit to Mogi-Coulomb strength criteria
  - A transition from tensile to shear failure was observed, rather than a tension cutoff

- Permeability and Fracture Evolution
  - Initial permeability and subsequent increases in permeability is highly dependent on the intermediate principal stress
  - Stress conditions coincident with permeability increases are also frictional/shear in nature
  - During unloading and reloading cycles, reactivation of crack networks occur due to shear stresses

- Numerical Modeling Comparisons
  - Consistently and accurately replicated strength and failure behavior
  - Inconclusive observations from fracture network development

Future Work

- Development of a failure criterion applicable to the tensile-shear transition region for this sandstone
- Expanding this testing to other materials
- Comparing damage with the increases in permeability using acoustic emissions
- Additional numerical simulation calibration with HOSS to determine causes of inconsistencies in fracture network geometry



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